Tactile Sensing Arrays for Humanoid Robots

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1. INTRODUCTION

The development of tactile sensors is one of the key technical challenges in advanced robotics and minimally invasive surgery. In this work we present arrays of 'taxels' (tactile elements) which will be placed on the distal phalange of the humanoid robot in our lab. Two different test designs and implementations are presented here. In the first one, microelectrode arrays (MEAs) of 32 elements, with 1mm center to center distance, have been designed. One taxel comprises of piezoelectric polymer film of PVDF-TrFE and an element of MEA. Each taxel is intended to be used as an extended gate of an FET (external to the chip); the taxel collects the charge/voltage generated, as consequence of the applied stress, on the deposited piezoelectric polymer film (i.e. the extended gate itself). The second design, each tactile element on the array comprises of piezoelectric polymer, PVDF-TrFE, directly deposited on the gate area of a FET device.

Keywords: MEA, Piezoelectric Polymer-FET (POSFET), Tactile Sensing

2. THE PRINCIPLE

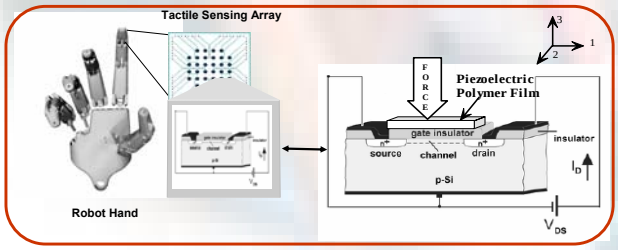


Figure 1. Proposed Tactile Sensing Arrays and overall approach.

A piezoelectric film working in the generating mode, gives a charge/voltage output when a mechanical force is applied. By depositing the piezoelectric polymer on the gate area of MOSFET, such a charge/voltage of the piezoelectric polymer can be used to modulate the charge in the induced channel of MOSFET which is then amplified by the MOSFET and further processed by electronic circuitry [1]. In addition to the reduction of electrical interference, such an integration of sensing elements with electronics on silicon will help in solving wiring complexity, which is a key problem in robotics. Overall approach is shown in Fig. 1. The distributed forces and contact points, obtained from the array can be used to find the physical properties like slip, shape, texture etc [2]. The fact that the frequency response of piezoelectric material changes with the contact material can be exploited not only to distinguish different materials but also to find the hardness/softness of the material.

3. ANALYTICAL STUDY

The equivalent model of a taxel implemented in SPICE and the simulated response are shown in Fig. 2. With SPICE model, the polymer is seen as an electrical network and thus the sensor design can be optimised by changing the parameters of polymer as well as that of electronics.

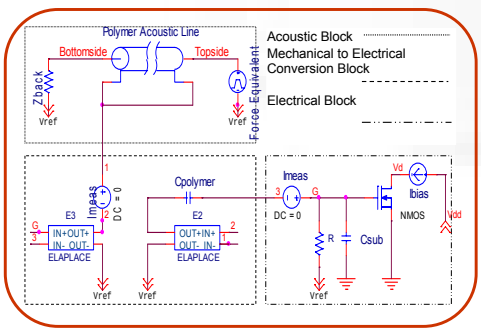
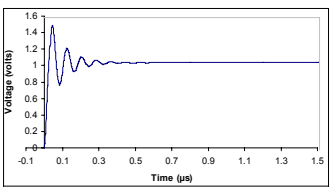
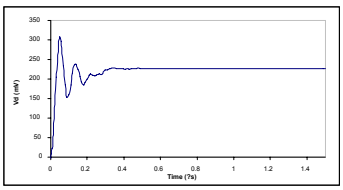


Figure 2. ***Left*: Model of a POSFET Tactile element on the array [3],[4].**

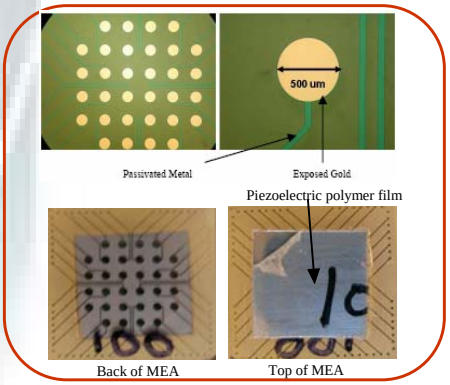
***Below*:** Simulated voltage output at node 3 and at drain terminal of FET device. A voltage equivalent of 0.1N of force was applied. The difference in magnitude of two responses is due to presence of the higher substrate capacitance (*Csub*) due to extended gate. Substrate capacitance is missing in the second design involving POSFET where polymer is directly deposited on the gate area of FET device.





4. DESIGN AND FABRICATION

Figure 4.
First Implementation: An MEA with 32 elements ('Taxels'). A 100 µm thick PVDF-TrFE polymer film epoxy adhered on the MEA, can also be seen [5].



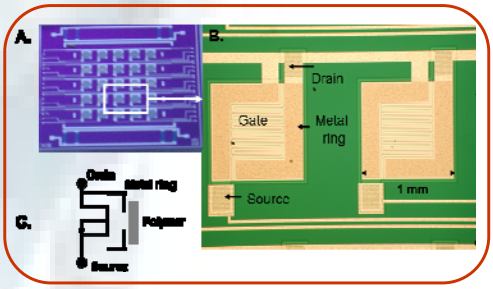
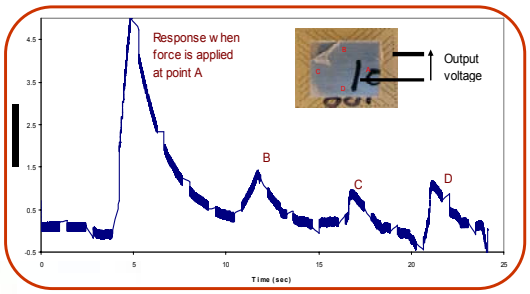


Figure 5
Second design: An array with 25 elements ('Taxels'). To obtain the POSFET tactile elements, a thin film of PVDF-TrFE will be spin coated on the gate area of the FET devices. The chip consists n-MOS elements with W/L = 300. The reference fabrication process for this second design is the n-MOS technological module of a non standard 4-µm Al gate p-well ISFET/CMOS technology [6]

4.RESULTS

Figure 6
The output from the MEA with a 100µm epoxy adhered polymer film. The force was applied on the taxel at point 'A', which is connected with the measuring instrument. The response of taxel at A, when force was applied at points B, C, and D is also shown. Thus. the point at which force is applied can be clearly observed.



5. CONCLUSIONS and FUTURE WORK

An approach for the development of a dynamic tactile sensing arrays for humanoid robots is presented along with the preliminary designs to test the piezoelectric polymers separately and with FET. The presented approach of miniaturizing the taxels, would significantly improve the overall robotics tactile sensing system. Future work will involve the study of electrical output from a single taxel as well as from the array, by applying forces in different directions, with different magnitudes and frequencies. For this purpose, a dynamic test set up is being developed.

In the next phase, a process for array of n-MOS devices with polymer spin coated on the gate will be realized and the complex circuits including both sensors and read-out will be accommodated on the same chip.

6. REFERENCES

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